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Dichloropropanes/Dichloropropenes Ambient Water Quality Criteria

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DICHLOROPROPANES/DICHLOROPROPENES

Ambient Water Quality Criteria

Criteria and Standards Division
Office of Water Planning and Standards
U.S. Environmental Protection Agency
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Section 304(a) of the Clean Water Act (33 U.S.C. 1314(a)), requires EPA to publish and periodically update water quality criteria. These criteria are to reflect the latest scientific knowledge on the identifiable effects of pollutants on public health and welfare, aquatic life, and recreation. This report presents water quality criteria for dichloropropanes and dichloropenes. It presents concentration criteria for the protection of fresh water and saltwater aquatic life. It presents 'safe' concentrations for humans, and in the case of suspect or proven carcinogens, gives various levels of incremental cancer risk. A section 304(a) water quality criterion is a qualitative or quantitative estimate of the concentration of a water constituent or pollutant in ambient waters which, when not exceeded, will ensure a water quality sufficient to protect a specified water use. Under the Act a criterion is a scientific entity, based solely on data and scientific judgement. It does not reflect consi....

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CRITERION DOCUMENT

DICHLOROPROPANES/DICHLOROPROPENES

CRITERIA

Aquatic Life

1,1-dichloropropane

The data base for freshwater aquatic life is insufficient to allow use of the Guidelines. The following recommendation is inferred from toxicity data for saltwater organisms and 1,3-dichloropropane.

For 1,1-dichloropropane the criterion to protect freshwater aquatic life as derived using procedures other than the Guidelines is 410 µg/l as a 24-hour average and the concentration should not exceed 930 µg/l at any time.

For saltwater aquatic life, no criterion for 1,1-dichloropropane can be derived using the Guidelines, and there are insufficient data to estimate a criterion using other procedures.

1,2-dichloropropane

The data base for freshwater aquatic life is insufficient to allow use of the Guidelines. The following recommendation is inferred from toxicity data for saltwater organisms and 1,3-dichloropropane.

For 1,2-dichloropropane the criterion to protect freshwater aquatic life as derived using procedures other than the Guidelines is 920 µg/l as a 24-hour average and the concentration should not exceed 2,100 µg/l at any time.

The data base for salt water aquatic life is insufficient to allow use of the Guidelines. The following recommenda-

tion is inferred from toxicity data on related chemicals and from data for saltwater and freshwater organisms.

For 1,2-dichloropropane the criterion to protect saltwater aquatic life as derived using procedures other than the Guidelines is 400 µg/l as a 24-hour average and the concentration should not exceed 910 µg/l at any time.

1,3-dichloropropane

The data base for freshwater aquatic life is insufficient to allow use of the Guidelines. The following recommendation is inferred from toxicity data for saltwater organisms and 1,3-dichloropropane.

For 1,3-dichloropropane the criterion to protect freshwater aquatic life as derived using procedures other than the Guidelines is 4,800 µg/l as a 24-hour average and the concentration should not exceed 11,000 µg/l at any time.

For 1,3-dichloropropane the criterion to protect saltwater aquatic life as derived using the Guidelines is 79 µg/l as a 24-hour average and the concentration should not exceed 180 µg/l at any time.

1,3-dichloropropene

For 1,3-dichloropropene the criterion to protect freshwater aquatic life as derived using the Guidelines is 18 µg/l as a 24-hour average and the concentration should not exceed 250 µg/l at any time.

The data base for saltwater aquatic life is insufficient to allow use of the Guidelines. The following recommendation is inferred from toxicity data for freshwater organisms.

For 1,3-dichloropropene the criterion to protect salt-water aquatic life as derived using procedures other than the Guidelines is 5.5 µg/l as a 24-hour average and the concentration should not exceed 14 µg/l at any time.

Human Health

For the protection of human health from the adverse effects of dichloropropanes and dichloropropenes ingested through the consumption of contaminated fish and water, the following criteria are suggested: dichloropropanes - 203 µg/l; dichloropropenes - 0.63 µg/l.

Introduction

Principal uses of dichloropropanes and dichloropropenes are as soil fumigants for the control of nematodes, in oil and fat solvents, and in dry cleaning and degreasing processes (Windholz, 1976). Dichloropropanes and dichloropropenes can enter the aquatic environment as discharges from industrial effluents, by runoff from agricultural land, and from municipal effluents. These compounds have been detected in New Orleans drinking water, although they were not quantified (Dowty, et al. 1975). Most data on persistence, degradation and distribution of dichloropropanes and dichloropropenes deal with their presence in soils.

Dichloropropanes and dichloropropenes are liquids at environmental temperatures that have molecular weights of 112.99 and 110.97, respectively (Weast, 1975). Composition of specific compounds are shown in Table 1.

Lange (1952) reports a water solubility of 270 mg/100 ml at 20°C for 1,2-dichloropropane. The vapor pressure of 1,2-dichloropropane is 40 mm Hg at 19.4°C (Sax, 1975). A review of various fumigants, fungicides, and nematocides by Goring and Hamaker (1972) lists the water solubility at 20°C as 0.27 percent for cis-1,3-dichloropropene and 0.28 percent for trans-1,3-dichloropropene.

Mixtures of 1,2-dichloropropane and cis- and trans-1,3-dichloropropene are used as soil fumigants. When heated to decomposition, 1,2-dichloropropane emits highly toxic fumes of phosgene, while 1,3-dichloropropene gives off toxic fumes of chlorides (Sax, 1975).

TABLE 1

Dichloropropanes	Boiling point (deg.C)	Density	Dichloropropenes	Boiling point (deg.C)	Density
1,1-PDC	88.1	1.132	1,1-DCP	76-77	1.186
1,2-PDC	96.4	1.156	1,2(cis)-DCP		
1,3-PDC	120.4	1.188	1,3(trans)-DCP	77	1.182
2,2-PDC	69.3	1.112	1,3(cis)-DCP	104.3	1.217
			1,3(trans)-DCP	112	1.224

Dichloropropenes have been shown to undergo photochemical formation of free radicals (Richerzhagen, et al. 1973). The cis and trans isomers of 1,3-dichloropropene have undergone biodehalogenation by a Pseudomonas species isolated from the soil (Belser and Castro, 1971). 1,3-Dichloropropene has been shown to react with biological materials (cow's milk, potatoes, humus-rich soil) to produce 3-chloroallyl methyl sulfide (Dekker, 1972).

It is determined that both dichloropropanes and dichloropropenes, like other pesticides, can be concentrated from the water column by low trophic-level organisms such as algae, which in turn can pass these compounds on to higher animals through the food chain. Specific instances of bioaccumulation and bioconcentration of these compounds by members of the aquatic environment are lacking.

In the non-aquatic environment, movement of dichloropropene and dichloropropane in the soil results from diffusion in the vapor phase, as these compounds tend to establish an equilibrium between concentrations in vapor, water and absorbing phases (Leistra, 1970). Degradation of certain of these compounds can occur in the soil. Van Dijk (1973) reports that cis- and trans-1,3-dichloropropene can be chemically hydrolyzed in moist soils to the corresponding 3-chloroalkyl alcohols, which are capable of metabolism to carbon dioxide and water by a bacterium (Pseudomonas sp.). Although field applications of 1,3-dichloropropene have shown between 15 and 80 percent decomposition (Van Dijk, 1973), the large amount that can be absorbed (80 to 90 percent) can

result in considerable residues existing months after application is completed (Leistra, 1970). 1,2-dichloropropane, however, appears to undergo minimal degradation in the soil, with the major route of dissipation appearing to be volatilization (Roberts and Stoydin, 1976). The persistence and degradation of dichloropropanes and dichloropropenes depends on susceptibility to hydrolysis (Thomason and McKenry, 1973), soil types (Leistra, 1970), and temperature (Van Dijk, 1973; Thomason and McKenry, 1973).

The actions of dichloropropanes and dichloropropenes on living organisms seems to depend upon the isomer (volatility, solubility, etc.) and the individual organisms. Additionally, judging by the rapid excretion of dichloropropanes and dichloropropenes in rats, it is unlikely that these compounds will remain and accumulate in mammals.

Dichloropropanes and dichloropropenes were both shown to be mutagenic but differed in degree. However, both were shown to have a low tumor causing potential if any at all.

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AQUATIC LIFE TOXICOLOGY*

FRESHWATER ORGANISMS

Introduction

The available freshwater aquatic life data for these two classes of compounds with one exception are for dichloropropanes. Where data exist for both 1,3-dichloropropene and 1,3-dichloropropane tested under similar conditions, the propene is much more toxic than the propane.

Acute Toxicity

The bluegill was exposed to 1,1-, 1,2-, and 1,3-dichloropropane under similar conditions (Table 1) and yielded unadjusted 96-hour LC50 values of 97,900, 280,000, and greater than 520,000 µg/l (Table 5), respectively (U.S. EPA, 1978). From these tests (Table 1) it appears that the toxicity decreases as the distance between the chlorine atoms increases with 1,2- being less toxic than 1,1-dichloropropane. Dawson, et al. 1977 reported a 96-hour LC50 value of 320,000 µg/l for bluegill exposed under similar

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*The reader is referred to the Guidelines for Deriving Water Quality Criteria for the Protection of Aquatic Life [43 FR 21506 (May 18, 1978) and 43 FR 29028 (July 5, 1978)] in order to better understand the following discussion and recommendation. The following tables contain the appropriate data that were found in the literature, and at the bottom of each table are the calculations for deriving various measures of toxicity as described in the Guidelines.

conditions to 1,2-dichloropropane and this result is similar to that previously mentioned.

The 96-hour LC50 value for 1,3-dichloropropene is 6,060 µg/l for bluegill (U.S. EPA, 1978). This LC50 value is approximately two orders of magnitude lower than that for 1,3-dichloropropane.

The Final Fish Acute Values for 1,1- and 1,2-dichloropropane and 1,3-dichloropropene are 14,000, 42,000, and 850 µg/l, respectively.

Daphnia magna is the only invertebrate species tested with these classes of compounds (Table 2). Under static test conditions the 48-hour EC50 values for 1,1-, 1,2-, and 1,3-dichloropropane were 23,000, 52,500, and 282,000 µg/l, respectively (U.S. EPA, 1978). As with the fish, the toxicity decreases with increasing distance between the chlorine atoms. The 48-hour EC50 value for 1,3-dichloropropene under static test conditions is 6,150 µg/l (U.S. EPA, 1978). This compound is many times more toxic than 1,3-dichloropropane.

Based on data for Daphnia magna, the Final Invertebrate Acute Values for 1,1-, 1,2-, and 1,3-dichloropropane and 1,3-dichloropropene are 930, 2,100, 11,000, and 250 µg/l, respectively. Since these concentrations are lower than the equivalent concentrations for fish, they also become the Final Acute Values.

Chronic Toxicity

An embryo-larval test has been conducted (Table 3) with the fathead minnow and 1,3-dichloropropene. The chronic value (122 µg/l) is obtained by dividing the geometric mean of the limits by two. After division of this chronic value by the species sensi-

tivity factor (6.7) a Final Fish Chronic Value of 18 µg/l is obtained for 1,3-dichloropropene.

No other chronic data are available for any dichloropropane or other dichloropropene.

Plant Effects

For 1,3-dichloropropene, the 96-hour EC50 values, based on chlorophyll a and cell numbers of the alga, Selenastrum capricornutum, were 4,950 and 4,960 µg/l, respectively (Table 4). The respective values for 1,3-dichloropropane are 48,000 and 72,200 µg/l. Thus the propene is much more toxic than the propane, as is true with the bluegill and Daphnia magna.

Residues

No measured steady-state bioconcentration factors (BCF) are available for any dichloropropane or dichloropropene. Bioconcentration factors can be estimated for the dichloropropanes using the octanol-water partition coefficients of 220, 105, and 100 for 1,1-, 1,2-, and 1,3-dichloropropane, respectively. These coefficients are used to derive estimated BCF's of 35, 20, and 19 for 1,1-, 1,2-, and 1,3-dichloropropane, respectively. An octanol-water partition coefficient was calculated for 1,3-dichloropropene to be 43 and this value is used to derive an estimated BCF of 10. These estimated BCFs for aquatic organisms assume approximately an eight percent lipid content. If it is known that the diet of the wildlife of concern contains a significantly different lipid content, appropriate adjustments in the estimated BCFs should be made.

Miscellaneous

In a test conducted on a mixed assemblage of emerald shiners and fathead minnows exposed to 1,3-dichloropropene, 100 percent of the fish survived three days at 1,000 µg/l, and none survived at 10,000 µg/l (Scott and Wolf, 1962). This is in general agreement with the value of 6,060 µg/l for the 96-hour LC50 value for the bluegill (U.S. EPA, 1978).

CRITERION FORMULATION

Freshwater-Aquatic Life

Summary of Available Data

The concentrations below have been rounded to two significant figures.

1,1-dichloropropane

Final Fish Acute Value = 14,000 µg/l

Final Invertebrate Acute Value = 930 µg/l

Final Acute Value = 930 µg/l

Final Fish Chronic Value = not available

Final Invertebrate Chronic Value = not available

Final Plant Value = not available

Residue Limited Toxicant Concentration = not available

Final Chronic Value = not available

0.44 x Final Acute Value = 410 µg/l

1-2-dichloropropane

Final Fish Acute Value = 42,000 µg/l

Final Invertebrate Acute Value = 2,100 µg/l

Final Acute Value = 2,100 µg/l

Final Fish Chronic Value = not available

Final Invertebrate Chronic Value = not available

Final Plant Value = not available

Residue Limited Toxicant Concentration = not available

Final Chronic Value = not available

0.44 x Final Acute Value = 920 µg/l

1,3-dichloropropane

Final Fish Acute Value = not available

Final Invertebrate Acute Value = 11,000 µg/l

Final Acute Value = 11,000 µg/l

Final Fish Chronic Value = not available

Final Invertebrate Chronic Value = not available

Final Plant Value = 48,000 µg/l

Residue Limited Toxicant Concentration = not available

Final Chronic Value = 48,000 µg/l

0.44 x Final Acute Value = 4,800 µg/l

1,3-dichloropropene

Final Fish Acute Value = 850 µg/l

Final Invertebrate Acute Value = 250 µg/l

Final Acute Value = 250 µg/l

Final Fish Chronic Value = 18 µg/l

Final Invertebrate Chronic Value = not available

Final Plant Value = 5,000 µg/l

Residue Limited Toxicant Concentration = not available

Final Chronic Value = 18 µg/l

0.44 x Final Acute Value = 110 µg/l

No freshwater criterion can be derived for any dichlopropane using the Guidelines because no Final Chronic Value for either fish or invertebrate species or a good substitute for either value is available.

However, data for 1,3-dichloropropane and saltwater organisms can be used as the basis for estimating criteria.

For 1,3-dichloropropane and saltwater organisms, 0.44 times the Final Acute Value is less than the Final Chronic Value derived from a life cycle test with the mysid shrimp. Therefore, a reasonable estimate of criteria for dichloropropanes and freshwater organisms would be 0.44 times the Final Acute Value. The lack of

a Final Fish Acute Value for 1,3-dichloropropane and freshwater fish is probably not important since the Final Fish Acute Value is greater than the Final Invertebrate Acute Value for all three cases with freshwater and saltwater organisms in which both values are available.

1,1-dichloropropane

The maximum concentration of 1,1-dichloropropane is the Final Acute Value of 930 µg/l and the estimated 24-hour average concentration is 0.44 times the Final Acute Value. No important adverse effects on freshwater aquatic organisms have been reported to be caused by concentrations lower than the estimated 24-hour average concentration.

CRITERION: For 1,1-dichloropropane the criterion to protect freshwater aquatic life as derived using procedures other than the Guidelines is 410 µg/l as a 24-hour average and the concentration should not exceed 930 µg/l at any time.

1,2-dichloropropane

The maximum concentration of 1,2-dichloropropane is the Final Acute Value of 2,100 µg/l and the estimated 24-hour average concentration is 0.44 times the Final Acute Value. No important adverse effects on freshwater aquatic organisms have been reported to be caused by concentrations lower than the estimated 24-hour average concentration.

CRITERION: For 1,2-dichloropropane the criterion to protect freshwater aquatic life as derived using procedures other than the Guidelines is 920 µg/l as a 24-hour average and the concentration should not exceed 2,100 µg/l at any time.

1,3-dichloropropane

The maximum concentration of 1,3-dichloropropane is the Final Acute Value of 11,000 µg/l and the estimated 24-hour average concentration is 0.44 times the Final Acute Value. No important adverse effects on freshwater aquatic organisms have been reported to be caused by concentrations lower than the estimated 24-hour average concentration.

CRITERION: For 1,3-dichloropropane the criterion to protect freshwater aquatic life as derived using procedures other than the Guidelines is 4,800 µg/l as a 24-hour average and the concentration should not exceed 11,000 µg/l at any time.

1,3-dichloropropene

The maximum concentration of 1,3-dichloropropene is the Final Acute Value of 250 µg/l and the 24-hour average concentration is the Final Chronic Value of 18 µg/l. No important adverse effects on freshwater aquatic organisms have been reported to be caused by concentrations lower than the 24-hour average concentration.

CRITERION: For 1,3-dichloropropene the criterion to protect freshwater aquatic life as derived using the Guidelines is 18 µg/l as a 24-hour average and the concentration should not exceed 250 µg/l at any time.

Table 1. Freshwater fish acute values for dichloropropanes -- dichloropropenes

Organism	Bioassay Method *	Test Conc.**	Chemical Description	Time (hrs)	LC50 (ug/l)	Adjusted LC50 (ug/l)	Reference
Bluegill, *Lepomis macrochirus*	S	U	1,1-dichloro-propane	96	97,900	53,500	U.S. EPA, 1978
Bluegill, *Lepomis macrochirus*	S	U	1,2-dichloro-propane	96	320,000	174,900	Dawson, et al. 1977
Bluegill, *Lepomis macrochirus*	S	U	1,2-dichloro-propane	96	280,000	153,000	U.S. EPA, 1978
Bluegill, *Lepomis macrochirus*	S	U	1,3-dichloro-propene	96	6,060	3,310	U.S. EPA, 1978

* S = static

** U = unmeasured

Geometric mean of adjusted values: 1,1-dichloropropane = 53,500 µg/l $\frac{53,500}{3.9}$ = 14,000 µg/l

1,2-dichloropropane = 163,600 µg/l $\frac{163,600}{3.9}$ = 42,000 µg/l

1,3-dichloropropene = 3,310 µg/l $\frac{3,310}{3.9}$ = 850 µg/l

Table 2. Freshwater invertebrate acute values for dichloropropanes - dichloropropenes (U.S. EPA, 1978)

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (ug/l)	Adjusted LC50 (ug/l)
Cladoceran, Daphnia magna	S	U	1,1-dichloro-propane	48	23,000	19,500
Cladoceran, Daphnia magna	S	U	1,2-dichloro-propane	48	52,500	44,500
Cladoceran, Daphnia magna	S	U	1,3-dichloro-propane	48	282,000	239,000
Cladoceran, Daphnia magna	S	U	1,3-dichloro-propene	48	6,150	5,210

* S = static

** U = unmeasured

Geometric mean of adjusted values: 1,1-dichloropropane = 19,500 µg/l $\frac{19,500}{21}$ = 930 µg/l

1,2-dichloropropane = 44,500 µg/l $\frac{44,500}{21}$ = 2,100 µg/l

1,3-dichloropropane = 239,000 µg/l $\frac{239,000}{21}$ = 11,000 µg/l

1,3-dichloropropene = 5,210 µg/l $\frac{5,210}{21}$ = 250 µg/l

Table 3. Freshwater fish chronic values for dichloropropanes - dichloropropenes (U.S. EPA, 1978)

Organism	Test	Limits (ug/l)	Chronic Value (ug/l)
		1,3-dichloropropene	
Fathead minnow *Pimephales promelas*	E-L*	180-330	122

* E-L = embryo-larval

Geometric mean of chronic values = 122 µg/l $\frac{122}{6.7}$ = 18 µg/l

Lowest chronic value = 122 µg/l

Table 4. Freshwater plant effects for dichloropropanes - dichloropropenes (U.S. EPA, 1978)

Organism	Effect	Concentration (ug/l)
	1,3-dichloropropene	
Alga, Selenastrum capricornutum	Chlorophyll a EC50 after 96 hr	4,950
Alga, Selenastrum capricornutum	Cell numbers EC50 after 96 hr	4,960
	1,3-dichloropropane	
Alga, Selenastrum capricornutum	Chlorophyll a EC50 after 96 hr	48,000
Alga, Selenastrum capricornutum	Cell numbers EC50 after 96 hr	72,200

Lowest plant value: 1,3-dichloropropene = 4,950 µg/l

1,3-dichloropropane = 48,000 µg/l

Table 5. Other freshwater data for dichloropropanes - dichloropropenes

Organism	Test Duration	Effect	Result µg/l	Reference
1,3-dichloropropene				
Mixture of - Emerald shiner, Notropis atherinoides acutus and Fathead minnow, Pimephales promelas	3 days	Mortality	100% survival at 1,000 100% mortality at 10,000	Scott and Wolf, 1962
1,3-dichloropropane				
Bluegill, Lepomis macrochirus	96 hrs	LC50	>520,000	U.S. EPA, 1978

SALTWATER ORGANISMS

Introduction

The data base for dichloropropanes and dichloropropenes and saltwater organisms is limited to studies with 1,2-dichloropropane, 1,3-dichloropropane, and 1,3-dichloropropene. Toxicity tests with saltwater organisms have not been done on other chemicals in this class and effects of salinity, temperature, or other water quality factors on toxicity are unknown. Only one fish and one invertebrate species have been tested with individual dichloropropanes and dichloropropenes.

Acute Toxicity

The unadjusted 96-hour LC50 values (Table 6) were 240,000 µg/l for 1,2-dichloropropane and the tidewater silverside (Dawson et al. 1977), 86,700 µg/l for 1,3-dichloropropane, and 1,770 µg/l for 1,3-dichloropropene and the sheepshead minnow (U.S. EPA, 1978). The adjusted LC50 value for 1,3-dichloropropane is 49 times greater than that for 1,3-dichloropropene. The LC50 value for 1,2-dichloropropane and the tidewater silverside is much greater than those for 1,3-dichloropropane and 1,3-dichloropropene and the sheepshead minnow, but it is impossible to tell whether the difference is due to different toxicities of the chemicals or responses of the species. When the adjusted LC50 values are divided by the Guidelines species sensitivity factor, the following Final Fish Acute Values are obtained: 1,3-dichloropropene, 260 µg/l; 1,3-dichloropropane, 13,000 µg/l; 1,2-dichloropropane, 35,000 µg/l.

Mysidopsis bahia, the only invertebrate species tested in acute tests, was more sensitive than the fishes (Table 7). For

mysid shrimp, 1,3-dichloropropene (96-hour LC50 = 790 µg/l) was 13 times more toxic than 1,3-dichloropropane (96-hour LC50 = 10,300 µg/l). Comparable data for Daphnia magna (Table 2) show that 1,3-dichloropropene was 46 times more toxic than 1,3-dichloropropane. When the adjusted LC50 values for each compound are divided by the species sensitivity factor (49), the Final Invertebrate Acute Values are 14 µg/l for 1,3-dichloropropene and 180 µg/l for 1,3-dichloropropane.

Chronic Toxicity

Only one study on chronic toxicity of dichloropropanes and dichloropropenes to saltwater organisms has been found (Table 8). In a life-cycle study with the mysid shrimp, the chronic value for 1,3-dichloropropane was 3,040 µg/l (U.S. EPA, 1978). When this result is adjusted by the species sensitivity factor (5.1), the Final Invertebrate Chronic Value is 600 µg/l for 1,3-dichloropropane, a value higher than that for Invertebrate Acute Value (180 µg/l). This is the result of a larger sensitivity factor for the acute toxicity data and the fact that the 96-hour LC50 value (10,300 µg/l) for the mysid shrimp is close to the chronic value (3,040 µg/l) for the same species.

Plant Effects

The saltwater alga, Skeletonema costatum, was as sensitive to 1,3-dichloropropene as fishes and mysid shrimp (Table 9). The 96-hour EC50 value for growth, based on concentrations of chlorophyll a in culture, was 1,000 µg/l. The EC50 calculated from cell numbers was 1,040 µg/l.

As with fishes and mysids, 1,3-dichloropropane was less toxic to Skeletonema costatum than 1,3-dichloropropene. The 96-hour

EC50 value from data for chlorophyll a was 65,800 µg/l; for cell number it was 93,600 µg/l.

There are no data reported in the literature on effects of dichloropropanes or dichloropropenes on saltwater vascular plants.

Residues

No measured steady-state bioconcentration factors (BCF) are available for any dichloropropane or dichloropropene. Bioconcentration factors can be estimated for the dichloropropanes using the octanol-water partition coefficients of 220, 105, and 100 for 1,1-, 1,2-, and 1,3-dichloropropane, respectively. These coefficients are used to derive estimated BCF's of 35, 20, and 19 for 1,1-, 1,2-, and 1,3-dichloropropane, respectively. An octanol-water partition coefficient was calculated for 1,3-dichloropropene to be 43 and this value is used to derive an estimated BCF of 10. These estimated BCFs for aquatic organisms assume approximately an eight percent lipid content. If it is known that the diet of the wildlife of concern contains a significantly different lipid content, appropriate adjustments in the estimated BCFs should be made.

Miscellaneous

No other data for dichloropropanes or dichloropropenes have been found for saltwater species.

CRITERION FORMULATION

Saltwater-Aquatic Life

Summary of Available Data

The concentrations below have been rounded to two significant figures.

1,2-dichloropropane

Final Fish Acute Value = 35,000 µg/l

Final Invertebrate Acute Value = not available

Final Acute Value = 35,000 µg/l

Final Fish Chronic Value = not available

Final Invertebrate Chronic Value = not available

Final Plant Value = not available

Residue Limited Toxicant Concentration = not available

Final Chronic Value = not available

0.44 x Final Acute Value = 15,000 µg/l

1,3-dichloropropane

Final Fish Acute Value = 13,000 µg/l

Final Invertebrate Acute Value = 180 µg/l

Final Acute Value = 180 µg/l

Final Fish Chronic Value = not available

Final Invertebrate Chronic Value = 600 µg/l

Final Plant Value = 66,000 µg/l

Residue Limited Toxicant Concentration = not available

Final Chronic Value = 600 µg/l

0.44 x Final Acute Value = 79 µg/l

1,3-dichloropropene

Final Fish Acute Value = 260 µg/l

Final Invertebrate Acute Value = 14 µg/l

Final Acute Value = 14 µg/l

Final Fish Chronic Value = not available

Final Invertebrate Chronic Value = not available

Final Plant Value = 1,000 µg/l

Residue Limited Toxicant Concentration = not available

Final Chronic Value = 1,000 µg/l

0.44 x Final Acute Value = 6.2 µg/l

1,3-dichloropropane

The maximum concentration of 1,3-dichloropropane is the Final Acute Value of 180 µg/l and the 24-hour average concentration is 0.44 times the Final Acute Value. No important adverse effects on saltwater aquatic organisms have been reported to be caused by concentrations lower than the 24-hour average concentration.

CRITERION: For 1,3-dichloropropane the criterion to protect saltwater aquatic life as derived using the Guidelines is 79 µg/l as a 24-hour average and the concentration should not exceed 180 µg/l at any time.

1,2-dichloropropane

No saltwater criterion can be derived for 1,2-dichloropropane using the Guidelines because no Final Chronic Value for either fish or invertebrate species or a good substitute for either value is available.

However, data for 1,3-dichloropropane and saltwater organisms and 1,2-dichloropropane and freshwater organisms can be used to estimate a criterion for 1,2-dichloropropane.

For 1,3-dichloropropane and saltwater organisms the Final Invertebrate Acute Value divided by the Final Fish Acute Value is 180 µg/l/13,000 µg/l = 0.014. The comparable quotient for 1,2-dichloropropane and freshwater organisms is 2,100 µg/l/57,000 µg/l = 0.037. The average quotient is 0.026. Multiplying this value times the Final Acute Value for 1,2-dichloropropane and saltwater fish results in an estimated Final Invertebrate Acute Value of 0.026 x 35,000 µg/l = 910 µg/l. Thus the estimated Final Acute Value for 1,2-dichloropropane is 910 µg/l. Multiplying this Final Acute Value by 0.44 gives 400 µg/l.

For 1,3-dichloropropane and saltwater organisms, 0.44 times the Final Acute Value is less than the Final Chronic Value derived from a life cycle test with the mysid shrimp. Therefore, a reasonable estimate of a criterion for 1,2-dichloropropane and saltwater organisms would be 0.44 times the Final Acute Value.

The maximum estimated concentration of 1,2-dichloropropane is the Final Acute Value of 910 µg/l and the estimated 24-hour average concentration is 0.44 times the Final Acute Value. No important adverse effects on saltwater aquatic organisms have been reported to be caused by concentrations lower than the estimated 24-hour average concentration.

CRITERION: For 1,2-dichloropropane the criterion to protect saltwater aquatic life as derived using procedures other than the Guidelines is 400 µg/l as a 24-hour average and the concentration should not exceed 910 µg/l at any time.

1,1-dichloropropane

No saltwater criterion can be derived for 1,1-dichloropropane using the Guidelines because no Final Chronic Value for either

fish or invertebrate species or a good substitute for either value is available, and there are insufficient data to estimate a criterion using other procedures.

1,3-dichloropropene

No saltwater criterion can be derived for 1,3-dichloropropene using the Guidelines because no Final Chronic Value for either fish or invertebrate species or a good substitute for either value is available.

However, data for 1,3-dichloropropene and freshwater fish can be used to estimate a criterion for 1,3-dichloropropene.

For 1,3-dichloropropene and freshwater fish the Final Chronic Value divided by the Final Acute Value is 18 µg/l/850 µg/l = 0.021 Multiplying this value times the Final Acute Value for 1,3-dichloropropene and saltwater fish results in an estimated Final Fish Chronic Value of 0.021 x 260 µg/l = 5.5 µg/l. Thus the estimated Final Chronic Value is 5.5 µg/l and is slightly lower than 0.44 times the Final Acute Value.

The maximum concentration of 1,3-dichloropropene is the Final Acute Value of 14 µg/l and the estimated 24-hour average concentration is the Final Chronic Value of 5.5 µg/l. No important adverse effects on saltwater aquatic organisms have been reported to be caused by concentrations lower than the estimated 24-hour average concentrations.

CRITERION: For 1,3-dichloropropene the criterion to protect saltwater aquatic life as derived using procedures other than the Guidelines is 5.5 µg/l as a 24-hour average and the concentration should not exceed 14 µg/l at any time.

Table 5. Marine fish acute values for dichloropropanes - dichloropropenes

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (ug/l)	Adjusted LC50 (ug/l)	References
Sheepshead minnow, Cyprinodon variegatus	S	U	1,3-dichloropropene	96	1,770	968	U.S. EPA, 1978
Sheepshead minnow, Cyprinodon variegatus	S	U	1,3-dichloropropane	96	86,700	47,399	U.S. EPA, 1978
Tidewater silverside, Menidia beryllina	S	U	1,2-dichloropropane	96	240,000	131,208	Dawson, et al. 1977

* S = static

** U = unmeasured

Geometric mean of adjusted values: 1,3-dichloropropene = 968 ug/l $\frac{968}{3.7}$ = 260 ug/l

1,3-dichloropropane = 47,399 ug/l $\frac{47,399}{3.7}$ = 13,000 ug/l

1,2-dichloropropane = 131,208 ug/l $\frac{131,208}{3.7}$ = 35,000 ug/l

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Table 7. Marine invertebrate acute values for dichloropropanes - dichloropropenes (U.S. EPA, 1978)

Organism	Bioassay Method*	Test Conc.**	Chemical Description	Time (hrs)	LC50 (ug/l)	Adjusted LC50 (ug/l)
Mysid shrimp, Mysidopsis bahia	S	U	1,3-dichloropropene	96	790	669
Mysid shrimp, Mysidopsis bahia	S	U	1,3-dichloropropane	96	10,300	8,724

* S = static

** U = unmeasured

Geometric mean of adjusted values: 1,3-dichloropropene = 669 ug/l $\frac{669}{49}$ = 14 ug/l

1,3-dichloropropane = 8,724 ug/l $\frac{8,724}{49}$ = 180 ug/l

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Table 8. Marine invertebrate chronic values for dichloropropanes - dichloropropenes (U.S. EPA, 1978)

Organism	Test*	Limits (ug/l)	Chronic Value (ug/l)
Mysid shrimp, *Mysidopsis bahia*	LC	2,200-4,200	3,040**

* LC = life cycle or partial life cycle

** 1,3-dichloropropane

Geometric mean of chronic values = 3,040 µg/l $\quad \frac{3,040}{5.1} = 600$ µg/l

Lowest chronic value =3,040 µg/l

Table 9. Marine plant effects for dichloropropanes - dichloropropenes (U.S. EPA, 1978)

Organism	Effect	Concentration (ug/l)
	1,3-dichloropropene	
Alga, Skeletonema costatum	Chlorophyll a EC50 after 96 hrs	1,000
Alga, Skeletonema costatum	Cell number EC50 after 96 hrs	1,040
	1,3-dichloropropane	
Alga, Skeletonema costatum	Chlorophyll a EC50 after 96 hrs	65,800
Alga, Skeletonema costatum	Cell number EC50 after 96 hrs	93,600

Final plant value: 1,3-dichloropropene = 1,000 ug/l

1,3-dichloropropane = 65,800 ug/l

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Mammalian Toxicology and Human Health Effects

EXPOSURE

Introduction

For purposes of discussion in this document, "dichloropropane" refers to 1,2-dichloropropane and will be abbreviated "PDC" (for propylene dichloride); "dichloropropene" refers to 1,3-dichloropropene and will be abbreviated "DCP." In the case of the latter, the cis- or trans- isomer will be designated when known. Lack of such designation will indicate lack of further information on speciation or that a mixture of the two isomers is involved.

PDC and DCP are used primarily as soil fumigants alone or in combination. PDC is also used as a solvent and a chemical intermediate, though comparative data concerning quantities utilized for pesticide and non-pesticide purposes were not found. 'D-D' is the Shell trademark for a combination preparation. The published analyses of this preparation vary, as seen in Table 1. 'Telone' is the Dow trademark for DCP. De Lorenzo, et al. (1977) described mutagenicity studies with Telone^{R} containing 30 percent of each isomer of DCP and 20 percent DCP. Telone 2^{R} described by Nater and Gooskens (1976) contains about 92 percent DCP and 3 to 5 percent PDC. PDC has also been marketed in combination with chlorpicrin; DCP has been marketed in combination with ethylene dibromide and carbon tetrachloride (Dowfume EB-5^{R}).

TABLE 1

Published Analytical Data on D-D(R) Soil Fumigant

	Composition (%)			
	Martin & Worthing (1974)	Spencer (1973)	De Lorenzo, et al. (1977)	Nater & Gooskens (1976)
1,3 dichloropropene	nlt 50	60-66	40	53
cis	+[a]	30-33	+	+
trans	+	30-33	+	+
1,2-dichloropropane	+	30-35	2	27
Other Chlorinated Hydrocarbons[b]	+	5		20

a: +, present but quantity not indicated

b: Other chlorinated hydrocarbons reported include one or more of: 3,3-dichloropropene; 2,3-dichloropropene; 1,2-dichloropropene; 2,2-dichloropropane; 1,2,3-trichloropropane, epichlorohydrin; allyl chloride.

Both PDC and DCP are volatile. The extent of this volatility is, as will be seen, an important consideration for interpretation of toxicological data and establishment of water quality criteria. Stanford Research Institute (1975) in a study for the National Science Foundation, reported that 60 million pounds per year of a mixture of DCP/PDC were produced for use as a soil fumigant. Thus, there is a potential for contamination of water and food via the soil.

Ingestion from Water

Dichloropropane and dichloropropene can enter the aquatic environment as discharges from industrial and manufacturing processes, as run-off from agricultural land, and from municipal effluents. These compounds have been identified but not quantified in New Orleans drinking water (Dowty, et al. 1975). The National Academy of Science's Safe Drinking Water Committee (1977) lists both PDC and DCP as organic contaminants found in finished drinking water, with no available information on chronic toxicity and with the highest concentration in finished water of 1.0 ug/l for each compound.

Ingestion from Food

Most data on the persistence, degradation, and distribution PDC and DCP deal with their presence in soils. Following field application, movement of these compounds in the soil results from vapor phase diffusion (Leistra, 1970). The rate of degradation of PDC and DCP in soil depends on the susceptibility to hydrolysis, soil types, soil temperature, and soil moisture (Thomason and McKenry, 1973; Leistra, 1970; Van Dijk, 1974). For example, cis-DCP is chemically hydrolyzed in moist soils to the corresponding cis-3-chloroallyl alcohol, which can be microbially degraded to carbon dioxide and water by Pseudomonas sp. (Van Dijk, 1974).

The distribution of PDC and DCP within soils depends upon soil conditions. These same conditions in turn influence their potential as persistent health hazards as soil contaminants, potentially toxic to developing crop plants. When applied at recommended rates, field applications of DCP

have shown between 15 to 80 percent decomposition after several weeks (Van Dijk, 1974). The remaining residues may exist for several months following application (Williams, 1968; Leistra, 1970). When Telone^{R} is applied to a moist, warm soil at a rate of 234 liters per hectare, cis-DCP can be expected to remain in the soil at concentrations greater tha 10 µg/l of soil for two to four months, depending on the soil type (Thomason and McKenry, 1973). Under certain conditions developing roots and tubers of crop plants can absorb small quantities of the remaining compounds (Williams, 1968). However, fumigation of sandy soils with relatively low dosage of alkyl nematocides under proper conditions produced no residues of nematocides and had no adverse effects on the flavor or nutritional value of lima beans, carrots, or citrus fruits (Emerson, et al. 1969). These were the only food crops tested. No information was found concerning the concentrations of the PDC and DCP in commercial food stuffs. Thus, the amount of these compounds ingested by humans through food is not known.

A bioconcentration factor (BCF) relates the concentration of a chemical in water to the concentration in aquatic organisms, but BCF's are not available for the edible portions of all four major groups of aquatic organisms consumed in the United States. Since data indicate that the BCF for lipid-soluble compounds is proportional to percent lipids, BCF's can be adjusted to edible portions using data on percent lipids and the amounts of various species consumed by Americans. A recent survey on fish and shellfish consumption

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in the United States (Cordle, et al. 1978) found that the per capita consumption is 18.7 g/day. From the data on the nineteen major species identified in the survey and data on the fat content of the edible portion of these species (Sidwell, et al. 1974), the relative consumption of the four major groups and the weighted average percent lipids for each group can be calculated:

Group	Consumption (Percent)	Weighted Average Percent Lipids
Freshwater fishes	12	4.8
Saltwater fishes	61	2.3
Saltwater molluscs	9	1.2
Saltwater decapods	18	1.2

Using the percentages for consumption and lipids for each of these groups, the weighted average percent lipids is 2.3 for consumed fish and shellfish.

No measured steady-state bioconcentration factors (BCF) are available for either dichloropropenes or dichloropropanes; however, the equation "Log BCF = 0.76 Log P - 0.23" can be used (Veith, et al. Manuscript) to estimate the BCF for aquatic organisms that contain about eight percent lipids from the octanol-water partition coefficient (P). An adjustment factor of 2.3/8.0 = 0.2875 can be used to adjust the estimated BCF from the 8.0 percent lipids that is the weighted average for consumed fish and shellfish. Thus, the weighted average bioconcentration factor for edible portions of all aquatic organisms consumed by Americans can be calculated.

Compound	P	BCF	Weighted BCF
1,1-dichloropropane	220	35	10
1,2-dichloropropane	105	20	5.8
1,3-dichloropropane	100	19	5.5
1,3-dichloropropane	43	10	2.9

Inhalation

The atmospheric levels of PDC and DCP are not known. However, the possible sources of entry of these compounds to the atmosphere are from the manufacture of commercial fumigants, the production of oil and fat solvents, the agricultural use, of fumigants, and from the use of PDC and DCP in drycleaning and degreasing processes. The exact amounts of PDC and DCP which each of the sources contribute to the atmosphere could not be ascertained.

Fumigant mixtures of PDC and DCP are applied to the soil in liquid form, usually by means of a chisel applicator. Small amounts of these mixtures escape into the atmosphere by natural diffusion up through the soil profile and some may leak into the atmosphere from the soil surface through inadequately sealed chisel shank holes. An estimate of the total amount of cis-DCP lost to the atmosphere after a typical application of Telone^{R} to a 30.5 cm depth in a warm, moist sandy loam soil would amount to approximately five to ten percent (Thomason and McKenry, 1973). The California State Department of Agriculture reported that in 1971 approximately 1,285 metric tons of pesticide containing

DCP were used in that State. It can be estimated that approximately 72 tons or eight percent of DCP were lost to the atmosphere (Calif. State Dep. Agric. 1971).

Since levels of the PDC and DCP have not been measured in the atmosphere it is impossible to determine the amounts of these compounds that could be inhaled by the general public. However, there is an occupational risk to the workers that handle these compounds, though information on actual exposure levels is not available in the published literature.

Dermal

Dermal exposure to the PDC and DCP is of concern to people who must work with these compounds. This is especially true for the agricultural workers who must mix and apply these compounds to the fields.

PHARMACOKINETCS

No data were revealed which deal with the absorption, distribution, biotransformation, or elimination of PDC or DCP in humans. Only one report was found which deals with the pharmacokinetics of these compounds (Hutson, et al. 1971). This report deals primarily with the retention potential of the compounds; the presentation of data on which a pharmacokinetic model could be based is limited.

The investigators administered PDC and the cis- and trans- isomers of DCP to rats. For each of the compounds, six rats (200 to 250 grams, Carworth Farm E strain) of each sex were dosed via stomach tube with 0.5 ml of arachis oil solution of 1,2-dichlororo (1-^{14}C) propane (0.88 mg, 8.5 uCi), cis-1,3-dichloro (2-^{14}C) propene (2.53 mg, 7.68 uCi), or trans-1,3-dichloro (2-^{14}C) propene (2.70 mg, 8.50 uCi).

The excretion of radioactivity as percent of the administered dose was determined in the urine, feces and respired air of these animals at 24-hour intervals over a four-day period. The animals were sacrificed after the fourth day following the administration of the compounds and the radioactivity remaining in their carcasses was measured.

Data resulting from the study are shown in Tables 2a and 2b. The authors claim that 80 to 90 percent of administered radioactivity was eliminated within the first 24 hours. This would include the radioactivity in the expired air though the data for that fraction for the first 24 hours were not given.

If 80 percent of the administered dose is eliminated in 24 hours, this would mean a total elimination constant of approximately 0.07 hr^{-1}. Approximately 50 percent of the administered dose of PDC and trans-DCP was eliminated by the urine in 24 hours. This would represent an elimination constant for urine of approximately 0.03 hr^{-1}. The compounds, on the basis of their physical properties, should distribute in total body water. In a rat a compound distributed in total body water with no accompanying storage or biotransformation would have a urinary elimination constant of approximately 0.50 hr^{-1}. Thus, the decreased clearance seen is due either to the renal tubular reabsorption (decreased clearance), incorporation into virtual volume of distribution (increased apparent volume of distribution), or both. The last is the most likely with compensation occurring by biotransformation. In the case of cis-DCP, the participation of biotransformation is more evident.

TABLE 2a

Rates of Excretion of Radioactivity from Rats After the Oral Administration of Three Components of D-D. (Hutson, et al. 1971)

Compounds	Sex	Excretion of radioactivity (% of administered dose) in 24-hr periods (hr after administration) 0-24	24-48	48-72	72-96	Total (0-96 hr)
			Urine			
1,2-Dichloropropane	M	48.5 ± 5.23	1.9 ± 0.45	0.5 ± 0.12	0.2 ± 0.03	51.1 ± 5.27
	F	51.9 ± 1.59	1.8 ± 0.22	0.4 ± 0.06	0.3 ± 0.05	54.4 ± 1.48
cis-1,3-Dichloropropene	M	81.3 ± 2.76	1.9 ± 0.21	0.6 ± 0.14	0.3 ± 0.06	84.1 ± 2.94
	F	80.3 ± 5.34	1.2 ± 0.29	0.4 ± 0.23	0.4 ± 0.23	82.3 ± 5.18
trans-1,2-Dichloroproprene	M	54.6 ± 1.92	0.6 ± 0.06	0.3 ± 0.04	0.1 ± 0.02	55.6 ± 1.90
	F	58.7 ± 1.08	1.1 ± 0.16	0.5 ± 0.13	0.2 ± 0.09	60.5 ± 1.00
			Faeces			
1,2-Dichloropropane	M	5.0 ± 2.66	0.7 ± 0.10	0.9 ± 0.56	0.2 ± 0.08	6.8 ± 2.61
	F	3.8 ± 0.95	0.7 ± 0.12	0.2 ± 0.02	0.2 ± 0.02	4.9 ± 1.07
cis-1,3-Dichloropropene	M	2.0 ± 0.38	0.8 ± 0.28	0.3 ± 0.14	0.2 ± 0.08	3.3 ± 0.53
	F	1.4 ± 0.43	0.2 ± 0.04	0.1 ± 0.03	0.1 ± 0.05	1.8 ± 0.42
trans-1,3-Dichloropropene	M	1.3 ± 0.37	0.2 ± 0.11	0.4 ± 0.15	0.1 ± 0.05	2.0 ± 0.28
	F	1.9 ± 0.24	0.2 ± 0.10	0.2 ± 0.15	0.1 ± 0.02	2.4 ± 0.26

The values given are the means ±SEM for groups of six rats.

TABLE 2b

Recoveries of Radioactivity from Rats in the 4 Days Following Oral Administration of Three Components of D-D.
(percent of administered dose)
(Hutson, et al. 1971)

		Recovery of radioactivity		Exhaled Air	
Compounds	Sex	Urine	Feces	Carbon Dioxide*	Other volatile radioactivity*
1,2-Dichloropropane	M	51.1 ± 5.27	6.9 ± 2.61	----	----
	F	54.4 ± 1.48	4.9 ± 1.07	19.3 (5)	23.1 (5)
cis-1,3-Dichloropropene	M	84.4 ± 2.94	3.3 ± 0.53	5.3 (3)	----
	F	82.3 ± 5.18	1.8 ± 0.42	2.4 (3)	1.4 (2)
trans-1,3-Dichloropropene	M	55.6 ± 1.90	2.1 ± 0.28	22.7 (3)	----
	F	60.4 ± 1.00	2.3 ± 0.26	24.4 (3)	3.5 (2)

* Values given are means for the numbers of animals indicated in parentheses.
Except where indicated otherwise, values given are the means ±SEM for groups of six rats.

EFFECTS

Dichloropropane

Acute, Sub-acute and Chronic Toxicity

Table 3 shows the acute LD_{50} values which have been obtained for PDC and related compounds.

The earliest reference to the acute oral toxicity of the dichloropropanes in mammals was reported in a study of the anthelmintic action of orally administered dichloropropanes in dogs (Wright and Schaffer, 1932). An oral dose of 5,700 mg PDC per kilogram body weight caused loss of coordination and staggering 15 minutes after administration, complete lack of coordination after 90 minutes, followed by death 3½ hours later. An oral dose of 3,500 mg DCP per kilogram body weight caused staggering, partial narcosis, and death within 24 hours. The dogs killed by the oral administration of the dichloropropanes exhibited hypostatic congestion of the lungs, congestion of the kidneys and bladder, and hemorrhages in the stomach and respiratory tract. Pathologically the liver showed passive congestion and severe cloudy swelling, accumulation of large fat droplets in some lobules, and marked deposition of bile pigments around the central veins. The kidneys showed severe passive congestion and degeneration of the tubular epithelium. Oral doses as low as 350 mg of dichloropropanes per kilogram body weight caused moderately severe lesions in the liver, gastrointestinal tract, and kidneys (Wright and Schaffer, 1932).

A series of inhalation toxicology studies by Heppel and his coworkers provide some information as to the relative toxicity of PDC. Initial studies (Heppel, et al. 1946)

TABLE 3

List of LD_{50}'s for Dichloropropane and Dichloropropene

Compound	Route	Species	LD_{50} Value	Notes	Reference
1,2-dichloropropane	Inhalation	Rat	9224 mg/m^3	8 hr exposure - 3/6 mortality	Smyth, et al. 1969
	Oral	Rat	2200 mg/kg	Carworth-Wistar strain*	Smyth, et al. 1969
		Rat	2200 mg/kg	Russian Paper	Ekshtat, et al. 1975
		Guinea Pig	2000 to 4000 mg/kg	Lethal dose	Anon. 1967
	Dermal	Rabbit	10,200 mg/kg	Single dose skin penetration	Smyth, et al. 1969
1,1-dichloropropane	Oral	Rat	6500 mg/kg	Carworth-Wistar strain*	Smyth, et al. 1954
	Dermal	Rabbit	16,400 mg/kg	Single dose skin penetration	Smyth, et al. 1954
1,3-dichloropropene-1	Inhalation	Rat	4530 mg/m^3	Cumulative high acute toxicity	Hine, et al. 1953
		Mice			Hine, et al. 1953
	Oral	Rat	140 $\pm$ 25 mg/kg		Hine, et al. 1953
		Mice	300 $\pm$ 27 mg/kg		Hine, et al. 1953
	Dermal	Rabbit	2100 $\pm$ 260 mg/kg	Single dose skin penetration	Hine, et al. 1953
2,3-dichloro-1-propene	Oral	Rat	320 mg/kg	Carworth-Wistar strain*	Smyth, et al. 1962
	Dermal	Rabbit	1930 mg/kg	Single dose skin penetration	Smyth, et al. 1962
D-D(R) (Nematocide)	Inhalation	Rat	4530 mg/kg	Long-Evans strain	Hine, et al. 1953
	Oral	Rat	140 $\pm$ 25 mg/kg	Long-Evans strain	Hine, et al. 1953
		Mice	300 $\pm$ 27 mg/kg	Long-Evans strain	Hine, et al. 1953
Telone(R) (Nematocide)	Oral	Rat male	713 mg/kg		Torkelson & Oyen, 1977
		Rat female	470 mg/kg		Torkelson & Oyen, 1977

*Single dose oral toxicity after 14 days.

were done with rats, mice, guinea pigs, and rabbits (and dogs at 1,000 ppm) utilizing daily seven-hour exposure periods and a concentration range of 1,000 to 2,200 ppm. A concentration of 2,200 ppm was lethal to over 50 percent of the animals of all four species after up to eight exposures. Mice were the most sensitive, 10/11 dying before the completion of one exposure period. In addition, animals were exposed to 1,600 ppm of PDC but the data are no more revealing than that already presented.

Gross effects observed in the animals included weight loss, CNS depression (cortical and medullary), rales, and neuromuscular weakness. Prothrombin time, BSP excretion, total plasma protein, A/G ratio, BUN, and serum phosphate were not altered in the dogs which died after exposure to 1,000 ppm. Hematological studies indicated no changes except for "somewhat lower" red cell counts and hemoglobin in exposed rabbits.

Gross and histopathological examination revealed a range of liver abnormalities from visceral congestion to fatty degeneration to extensive multilobular areas of coagulation necrosis. Other pathological effects observed among animals from all concentrations included: renal tubular necrosis and fibrosis, splenic hemosiderosis, pulmonary congestion, bronchitis, and pneumonia and fatty degeneration in the heart. Subsequent studies utilizing 2,200 ppm were performed (Highman and Heppel, 1946) to obtain further pathological data. These studies served to further document the earlier observations. However, there might be a possibility of the presence of what we now refer to as drug-induced phospholipidoses.

In another study (Heppel, et al. 1948) rats, guinea pigs, and dogs were exposed to 400 ppm of PDC for 128 to 140 daily seven-hour periods (given five days per week). The only effect observed was a decreased weight gain by rats. However, considering the pharmacokinetic data discussed earlier, it may be that, by utilizing a five-day per week schedule, the investigators were not getting the prolonged exposure they might have expected.

Mice were then exposed in the same fashion. As in the previous study, mice (C57) were more sensitive to PDC; and apparent treatment-related "slight fatty degeneration of the liver" was observed.

Sidorenko, et al. (1976) studied the effects of the continuous inhalation of 1 and 2 mg PDC per liter air in albino male rats (200 to 400 grams). Blood acetylcholinesterase and blood catalase activities, red and white blood cell counts, hemoglobin, and animal weight were measured after 2, 4, 24, 48, 72, 96 hours and after six and seven days of continuous exposure. Histopathological examination of the liver and kidneys, determination of ribonocleic acid, glycogen, lipids, oxidation process (succinate dehydrogenase activity), DPN-diaphorase, acid and alkaline phosphatase, and quantitative evaluation of the liver DNA were performed on the exposed animals. Significant changes in catalase and cholinesterase activity and threshold index were observed as early as four hours after the start of the inhalation of 1.0 mg PDC per liter air. Significant changes occurred in all of the above mentioned tests after 24 hours of continuous exposure to 1.0 mg PDC per liter air.

The livers for rats that were continuously exposed to 1.0 mg PDC per liter air for seven days histologically showed proteinfat dystrophy, suppression of enzymic activity, and decreased ribonucleoproteins centralized in the centrolobular sections. Cells of peripheral sections of lobules showed fewer changes and underwent displacements of an adaptational nature in the form of hyperplasia and hypertrophy of cellular and intracellular structures. The number of unicellular polyploidal hepatocytes increased significantly whereas the number of binuclear cells was reduced. In some instances the amount of ploidy equalled 16n. These adaptive changes were accompanied by increased ribonucleoproteins and increased enzyme activity on the periphery of the hepatocytes. In the kidney, as in the liver, regions of greater or lesser sensitivity to PDC were found and adaptational changes were found in the distal segments of the nephron which showed increased activity (Sidorenko, et al. 1976).

The effect of PDC on the functional state of the rat was further demonstrated (Kurysheva and Ekshtat, 1975). Blood serum chloesterol, beta-lipo proteins and gamma-globulin levels increased after the 10th day of daily oral doses of 14.4 and 360 mg PDC per kilogram body weight. By day 20 of dosing, the serum cholinesterase was inhibited whereas the fructose-1-monophosphate aldolase, alanine transaminase, and asparagine transaminase were increased and after 30 days of dosing the alanine transaminase was inhibited.

In the range-finding studies of Smyth, et al. (1954, 1962, 1969), acute inhalation toxicity studies of new chemical compounds were performed to indicate the comparative hazards of handling these compounds and the degree of care necessary to protect the exposed workmen. The studies consisted of exposing groups of six male Carworth-Wistar rats (90 to 100 grams body weight) to either saturated vapors or known vapor concentrations of compounds for a known period of time and then observing the mortality of the exposed rats during a 14-day observation period. It was recorded that a group of six rats could survive a 10-minute exposure in a saturated vapor atmosphere of PDC with no death during the 14-day observation period. In another exposure study, one eight-hour exposure to 8.8 mg PDC per liter air killed three of six rats during the 14-day observation period (Smyth, et al. 1969). It was found that a group of six rats could survive an exposure of only two minutes in a saturated vapor atmosphere of 1,1-dichloropropane (7,630 mg 1,1-dichloropropane per liter air). One four-hour exposure to 17.6 mg 1,1-dichloropropane per liter air killed four of six rats within the 14-day observation period (Smyth, et al. 1954).

St. George (1937) described the effects of PDC poisoning in humans. Symptoms included headache, vertigo, lacrimation, and irritation of the mucous membrane. Changes in the blood are similar to those of "marked anemia."

Another case report described found the acute oral toxicity of PDC in a 46-year-old man who accidently ingested about 50 ml of a cleaning solution containing PDC. Within two hours after ingestion, he went into a deep coma with

mydriasis and hypertonia; after 24 hours he regained consciousness with treatment of artificial ventilation and osmotic diuresis. However, after 36 hours he went into irreversible shock and died of cardiac failure with lactic acidosis and hepatic cytolysis. Necropsy examination showed centro and mediolobular acute hepatic necrosis (Larcan, et al. 1977).

Mutagenicity

De Lorenzo, et al. (1977) reported PDC to be mutagenic in S. typhimurium strains TA 1535 and TA 100 with or without metabolic conversion. No such activity was found in TA 1978, TA 1537, or TA 98 (Table 4). This implies missense, but not frameshift mutations. However, this is further discussed in the section dealing with mutagenicity of DCP.

Bignami, et al. (1977) also reported the mutagenicity of PDC in TA 1535 and TA 100. They studied the induction of point mutations (8-azaguanine resistance) and somatic segregation (crossing over and non-disjunction) in A. nidulans, using the spot test technique. PDC was shown to significantly raise the frequency of mutants resistant to 9-azaguanine.

Dragusanu and Goldstein (1975) reported that PDC causes chromasomal aberrations in rat bone marrow. Trace impurities of PDC were tested and found to be inactive.

Carcinogenicity

In none of the studies described to this point was evidence of carcinogenicity observed. However, Heppel, et al. (1948) tried to induce hepatomas in C3H strain of mice by repeated inhalation of 1.76 mg PDC per liter air. Only three of 80 C3H strain mice survived a total of 37 exposure periods and a subsequent observation period of

TABLE 4

Mutagenicity of D-D®, Telone®, PDC and DCP as Determined by the "Ames" Test With (W) and Without (WO) Liver Microsomal Fraction. (De Lorenzo, et al. 1977)

			Number of mutant colonies/plate with Salmonella strains					
			TA 1978		TA 1535		TA 100	
Compound	Amount/plate		WO	W	WO	W	WO	W
Telone®	100	µg	24	115	12	15	178	151
	250	µg	36	225	48	59	225	191
	1	mg	45	249	75	90	263	242
	2.5	mg	53	270	115	135	425	385
	5	mg	61	365	150	220	282	500
	10	mg	15	150	78	61	192	212
D-D® soil fumigant	500	µg	11	123	35	42	125	112
	5	mg	38	181	45	61	198	25[illegible]
	15	mg	80	300	151	151	350	450
	25	mg	75	446	145	150	470	[illegible]12
cis-DCP	20	µg	19	21	243	77	594	731
	50	µg	90	71	680	490	1800	2100
	100	µg	119	131	1210	990	1750	1551
trans-DCP	20	µg	27	31	235	109	362	650
	50	µg	68	75	430	381	1750	2200
	100	µg	115	91	925	828	1820	1500
PDC	10	mg	27	38	75	81	220	185
	20	mg	38	21	210	185	480	450
	50	mg	48	15	411	312	850	920

7 months, at which time the three remaining mice were 13 months of age. These three mice showed multiple hepatomas histologically similar to those induced by carbon tetrachloride. The livers of these mice also-showed many large mononuclear cells laden with lipochrome resembling ceriod. Although inhalation of 1.76 mg PDC per liter air induced hepatomas, too few mice survived the exposures and observation period to make a statistically valid evaluation. No hepatomas were observed in control animals.

Dichloropropene

Acute, Sub-acute and Chronic Toxicity

Acute LD_{50} for DCP and isomers is given in Table 3. Most of the information on the toxicity of DCP comes from a study by Torkelson and Oyen (1977). Rats were exposed to 3 ppm (13.6 mg/m^3) for periods of 0.5, one, two, or four-hours/day, five days a week for six months. Only the rats exposed 4 hours per day showed an effect and this was manifested as cloudy swelling of the tubular epithelium. Further studies were done on rats, guinea pigs, and rabbits exposed to 1 or 3 ppm of DCP, 7 hours per day for 125 to 130 days over a 180-day period. Hematological studies were run midway and near the end of the study. No changes were seen in hematocrit, WBC, hemoglobin, or differential count, which could be attributed to the treatment. The only effect the authors described which could be attributed to treatment was cloudy swelling of renal tubular epithelium in male rats and an increase in liver weight/body weight ratio in female rats. Some rats were also allowed a three-month

recovery period. After this time no changes attributable to treatment were observed. In experiments preliminary to these (complete data not published), rats and guinea pigs were exposed to 50 ppm DCP, 7 hours per day for 19 out of 28 days and 27 out of 39 days. Changes attributable to treatment for the shorter period were equivocal. After the longer period, gross examination revealed some liver and kidney changes (Torkelson and Oyen, 1977). These authors also cited unpublished data of others indicating liver, kidney, and lung injury in animals receiving oral doses of DCP in the LD_{50} range. The studies of Torkelson and Oyen (1977) cited indicate 1 ppm DCP by inhalation as a NOAEL. The authors recommend this as a time-weighted TLV.

Strusevich and Ekshtat (1974) investigated the effects of DCP on the trypsin, trypsin inhibitor, amylase, and lipase activities in the blood serum of albino rats. The animals were fed daily doses of 0.1, 0.5 and 2.5 mg of DCP per kilogram body weight for six months. The results showed that the trypsin activity increased through the six months of administration and the activity of trypsin inhibitor decreased after the second month of administration. The blood lipase activity permanently increased, and amylase tended to be reduced.

Kurysheva and Ekshtat (1975) studied the effects of daily oral doses of DCP on the functional state of the rat liver. They fed groups of albino rats daily oral doses of 2.2 and 55 mg of DCP per kg for 30 days. The results showed that by day 30 of administration the excretory liver

function was altered as evidenced by prolonged pigment circulation in the blood, raised thymol test values, cholesterol level, and stimulated increase of fructose 1-monophosphate aldolase.

In human sensory tests, 13.6 mg air was detected by seven of ten human volunteers who were exposed to 11.6 or 4.5 mg DCP/mg^3 air for one to three minutes. Some of the volunteers reported fatiguing of the sense of smell after a few minutes of exposure. Seven of the ten volunteers were able to detect 4.5 mg/m^3 air, but it was noticeably fainter (Torkelson and Oyen, 1977).

Mutagenicity

De Lorenzo, et al. (1977) reported that DCP was mutagenic to S. typhimurium TA 1535 and TA 100 but not the TA 1978, TA 1538, or TA 98. Mutagenicity was the same with or without the addition of liver microsomal fraction. The authors concluded that because the results are similar to those seen with PDC, the same mechanistic implications may exist.

In another study, Neudecker, et al. (1977) found the cis- and trans- isomers of DCP to give positive results in an assay system with strains TA 1535, TA 1537, and TA 1538. Both isomers of DCP were mutagenic to strain TA 1535 with and without microsomal activation. The cis-isomer was found to be two times more reactive than the trans-isomer.

Neudecker, et al. (1977) also found a significant difference in the survival rate of the bacteria exposed to varying concentration of both isomers. At all concentrations tested, survival rates of cells exposed to cis- DCP were generally lower than those of bacteria exposed to the trans-isomer.

It can be seen from Table 4 that DCP may be about three orders of magnitude more mutagenic than PDC. Also, it can be seen that Telone^{R} and D-D^{R} (see Table 1 for composition of the products used in this study) are mutagenic to TA 1535 and TA 100, as might be expected. However, they are also mutagenic to TA 1978 (in the presence of microsomal fraction) indicating a frame-shift mutation. In the Criterion Formulation Section of this document it is suggested that mixtures of PDC and DCP may result in a negative deviation from Raoult's law. That is, the vapor pressure of the mixture is lower than the vapor pressure of either individual component. The implication is that less evaporation of material may occur when the mixture is used. Another possibility is that the presence of one compound results in the forcing of the other through an alternate or normally minor metabolic pathway, leading to the formation of larger amounts of a normally minor mutagenic metabolite.

Carcinogenicity

Van Duuren, et al. (In press) designed a study to evaluate the carcinogenicity of 15 halogenated hydrocarbons by a multiple bioassay procedure. From their studies, the authors have suggested certain structure/activity relationships concerning carcinogenicity and the bioassay procedure. Among the compounds studied was cis-DCP. The compound was studied by three procedures.

(1) Initiation-Promotion: 122 mg applied once in 0.2 ml actone followed 14 days later by 5 ug (in 0.2 ml acetone) of the tumor promoter, phorbol myristate acetate (PMA), three times weekly for 428 to 576 days.

(2) Repeated Skin Application: 41 or 122 mg in 0.2 ml acetone to shaved skin three times weekly for 400 to 494 days.

(3) Subcutaneous Injection: 3 mg in 0.05 ml trioctanoin injected subcutaneously in the left flank once weekly for 538 days.

All studies utilized 30 male ICR/Ha Swiss mice per group.

In the initiator-promotor studies, six papillomas in four mice were observed. This result was not significantly different from promotor controls. Repeated skin application revealed three papillomas in three mice for the 122 mg dose; this was not significantly different from control animals which had no tumors. No tumors were observed for the animals receiving the 41 mg dose.

In the case of subcutaneous administration, six mice developed local sarcomas which was statistically significant from controls (0/100). In none of the studies were treatment-related remote tumors observed.

Dichloropropane/Dichloropropene

(mixtures containing at least 10 percent PDC)

Acute, Sub-acute and Chronic Toxicity

Acute oral LD_{50} values for D-D^{R} are shown in Table 3. Hine, et al. (1953) reported gross behavioral responses to lethal and near lethal doses similar to those seen for PDC and DCP alone. Gross pathological examination of the rats that died showed distention of the stomach by fluids and gas and erosion of the gastrointestinal mucosa, with occasional hemorrhage. Hemorrhage of the lungs and fatty degeneration of the liver were occasionally seen in rats

that died after several days after administration. The mortality curve was abrupt; all mice died at the highest dose level(432 mg D-D^R/kg), about one-half at the next level (288 mg D-D^R/kg), and only one at the two lowest levels (192 and 132 mg D-D^R/kg body weight). Rats showed the same type of curve.

Hine, et al. (1953) also studied the acute inhalation toxicity of the commercial product D-D^R. They exposed 24 adult Long-Evans strain rats for four hours to concentrations of D-D^R ranging from 2,000 to 81,500 mg D-D^R/m^3. The exposure to D-D^R caused respiratory distress, dyspnea, hypernea, mucous nasal discharge, and lacrimation. Dilatation of the capillaries was evident in the ears. Gross pathological examination of the rats that died from the exposures showed severe edema of the lungs, with varying degrees of interstitial and alveolar hemorrhage, and distention of the stomach and upper small intestine. Congestion and fatty degeneration of the liver also were noted occasionally in animals exposed to D-D^R.

Russian scientists have investigated the effects of low oral and chronic doses of mixtures of dichloropropanes and dichloropropenes and D-D^R in the exocrine function of the rat pancreas, the central nervous system, the kidney function in rabbits, and the functional state of the liver (Strusevich and Ekshtat, 1974, Fedyanina, et al. 1975; Kurysheva, 1974; Kurysheva and Ekshtat, 1975).

Strusevich and Ekshtat (1974) studied the effect of D-D^R on the exocrine function of the pancreas by orally administering doses of 0.1, 0.6 and 3.0 mg D-D^R/kg body

weight to young male albino rats daily for six months. These doses of D-D^R caused an increase in trypsin and lipase activities and decreased the trypsin inhibitor activity of the blood.

The precutaneous absorption of the product D-D^R was studied by Hine, et al. (1953). Nineteen rabbits were depilated over the back and flanks in a cylindrical swath between the fore and hind legs, immobilized, and a tight-fitting girdle was slipped over the shaved area. Undiluted D-D^R in doses of 1200 and 4800 mg/kg body weight were introduced under the girdle and was allowed to remain in contact with the skin for 24 hours. The rabbits exhibited decreased body movement and depressed respiration. One rabbit receiving 3000 mg D-D^R/kg had developed mucous nasal discharge. Seven of the ten rabbits receiving the three higher doses of D-D^R died in 8 to 48 hours, and the five rabbits receiving the lowest dose (1200 mg D-D^R/kg) survived.

Three cases of untoward reaction to D-D^R have been reported in the Netherlands. Three patients had developed symptoms after several years of repeated exposures to the soil fumigant D-D^R during its application to the fields. Most of the dermal contact was through the feet caused by the D-D^R dripping inadvertantly into the shoes of the farmers during the spraying operation. By patch testing, the existence of a contact allergic sensitivity to D-D^R could be proven in one patient. Patch tests with compounds related to D-D^R suggest that the cause of contact allergy must be sought in the propene(s) fraction of D-D^R. All three patients

exhibited an itchy erythematous rash on the arms, face and ears following contact with D-D^{R} (Nater and Gooskens, 1976).

Mutagenicity

The mutagenicity of mixtures of PDC and DCP is discussed in the previous section.

Carcinogenicity

No data were retrived concerning the carcinogenicity of mixtures of PDC and DCP.

CRITERIA FORMULATION

Consideration of Mathematical Model

There are no carcinogenicity data on which water quality criteria for PDC and DCP can be based. Similarly, no-observable-adverse-effect-level data following oral administration of the compounds to man or experimental animals are not available. Consequently, the water quality criteria must be based on NOAEL's obtained from inhalation toxicology data.

The conversion of inhalation toxicology data to water quality standards is usually done by the procedure described by Stokinger and Woodward (1958). This procedure essentially involves an estimation of the daily intake of a substance if man was exposed to that substance according to the time and concentration limits of the NOAEL. This amount is then multiplied by a relative absorption factor expressed as "inhalation absorption factor/ingestion absorption factor" to give the amount of material which would have to be ingested daily to be equivalent to that amount of material absorbed during daily exposure to NOAEL levels.

There are a number of pitfalls to this approach. Since the final results of the calculations represent estimates, at best, most of the pitfalls are of theoretical rather than practical concern. However, there is one aspect of the calculation which is practically inestimatable without some biological data. This concerns estimation of relative absorption by various routes of administration. From pharmacokinetic concepts, much of which have become evident since

Stokinger and Woodward published their method, it is unreasonable to expect a justifiable estimate of relative absorption factors without experimental data relating route of administration to blood level. Because such data are not available for PDC and DCP, another approach was devised to extrapolate inhalation data to ingestion data.

The approach was based on the following:

$\lambda X_a = X_b$ where:

λ = Ostwald coefficient for vapor phase at 37° C

X_a = alveolar gas concentration = inhalation NOAEL

X_b = arterial blood concentration at equilibrium on exposure to X_a

Thus, if X_a can validly be calculated in this way, then the amount of material which would have to be ingested to yield that blood level at equilibrium, i.e., ingestion NOAEL can be expressed as follows:

Ingestion NOAEL = $k_{out} \times X_b \times V_D$ where:

k_{out} = fraction of body burden eliminated every 24 hours

V_D = apparent volume of distribution of the body burden in man (70 kg)

The allowable daily intake (ADI) can then be expressed in the usual fashion:

$$ADI = \frac{\text{Ingestion NOAEL}}{\text{uncertainty factor}}$$

All of the factors described are estimatable at one degree or another based on the data available for PDC and DCP. The derivation of the ingestion NOAEL has been done assuming that equilibrium is reached during conditions of the inhalation NOAEL and that the ingestion NOAEL is taken as a single dose. It is recognized that possibly the first

and certainly the second assumption does not represent the actual situation. However, the experimental data are too imprecise and the population habits too variable to make the correction of these assumptions. It should be recognized, however, that by utilizing these two assumptions the error is in the direction of underestimating the ingestion NOAEL.

Derivation of Ostwald Coefficient

The Ostwald coefficient (λ) is defined as the ratio of the concentration of a gas in a liquid to the concentration of the gas in an equivalent volume of gas above that liquid. By definition, the Ostwald coefficient of a gas and water at any particular temperature could be expressed:

$$\lambda = \frac{\text{water solubility (g/l)}}{\text{conc. or vapor (g/l) at a partial pressure equal to vapor pressure}}$$

In the criteria formulation, λ for water is used as that for blood. A review of data on volatile anesthetic agents indicated this approach was acceptable. The applicability of this procedure to estimation of X_b can be seen from the data of Heppel, et al. (1946). They determined blood concentration of PDC in rabbits and dogs after a seven-hour exposure period. From their exposure data, blood levels were calculated based on the Ostwald coefficient determined here (see below) and a hematocrit of 0.50. The data are as follows:

Animal	Exposure conc. (mg/l)	Blood conc. Found (mg/l)	Blood Conc. Calculated (mg/l)
Rabbits	10.3	15-29	28.6
Rabbits	6.0	6-11	16.7
Dogs	4.7	13-16	13.0

Dichloropropane

The data for the vapor pressure (P) were developed by Nelson and Young (1933). From their data it was determined that P ($20^{o}C$) = 40 mm Hg and P ($38^{o}C$) = 90 mm Hg. Unfortunately the only solubility data available were that for $20^{o}C$. However, data available on trichloroethylene and chloroform indicated that

$$\frac{P_{37^{o}}}{P_{20}} = 0.512$$

A similar relationship was found for ether. This factor was utilized for PDC:

Solubility in water = 2.7 g/l

Concentration in air = $n/v = \frac{P}{RT} = \frac{40}{62 \times 293} =$

$$0.0022 \text{ mole/l} = 0.25 \text{ g/l}$$

$$\lambda_{20^{o}} = \frac{2.7}{0.25} = 10.8$$

$$\lambda_{38^{o}} = 10.8 \times 0.512 = 5.5$$

Dichloropropene

A valid vapor pressure value for DCP could not be identified as such. However, the Fire Protection Guide on Hazardous Materials (1975) cited the vapor air density of DCP (cis and trans) as 1.4 at $37.8^{o}C$. Vapor air density (D) can be expressed as:

$$D = \frac{Pd}{P'} + \frac{P'-P}{P'}$$

where P = vapor pressure (at 37.8^{o})
P' = ambient pressure (760 mm Hg)
d = vapor density (3.8 for DCP)

Therefore

$$P = \frac{P'D-P'}{d-1} = 109 \text{ mm Hg}$$

This is a feasible relationship to the vapor pressure of 90 mm Hg at 38°C reported for PDC. An assumption of parallelism for plots of log vapor pressure vs. 1/T for PDC and DCP is reasonable. Thus the vapor pressure of DCP at 20°C can be assumed to be 59 mm Hg. This conversion is necessary since the only available solubility data for DCP is at 20°.

Thus

$$n/v = \frac{P}{RT} = \frac{59}{62 \times 293} = 0.0032 \text{ moles/l}$$
$$= 0.36 \text{ g/l}$$

solubility of DCP in water at 20° = 1.0 g/l

$$\lambda_{20^\circ} = \frac{1.0 \text{ g/l}}{0.36 \text{ g/l}} = 2.8$$

$$\lambda_{38^\circ} = 2.8 \times 0.512 = 1.4$$

D-D^R, as described by Martin and Worthing (1974) has a vapor pressure of 35 mm Hg at 20°; as described by Spencer (1973), it has a vapor pressure of 31.3 mm Hg at 20° C (see Table 1). If these values are accurate, then the mixture of PDC and DCP can be assumed to be a negative deviation from Raoult's law. Measurements of partial pressure of binary solutions show that most of them can be classified as deviating from Raoult's law, either positively or negatively. The implication of this behavior of mixtures of PDC and DCP has been discussed in the criterion document regarding the interpretation of mutagenicity data.

Derivation of Elimination Constant (k)

The derivation of k is the most speculative portion of the model. From the data presented earlier, it can be assumed that the rat excretes 80 percent of a dose in 24 hours. It is likely, however, that PDC and DCP fit a two compartment pharmacokinetic model, at the least. Only the first (water) compartment in the rat can be reasonably estimated from the data available. Based on differences in glomerular filtration rate/weight relationships between rat and man, the k of a rat was reduced from $0.80 \times 24\ hr^{-1}$ to $0.25 \times 24\ hr^{-1}$. This is a moderate estimate which should also allow for known higher rates of biotransformation in the rat when compared to man.

Derivation of Volume of Distribution

The volume of distribution (V_D) of the compounds was assumed to be in a total body water plus fat:

Thus

$$V_D = V_{TBW} + (V_F \times \lambda_{W/F})$$

where

V_{TBW} = volume of total body water (36L in 70 kg man)

V_F = volume of fat (10 l in 70 kg man)

$\lambda_{W/F} = \lambda_{O/W}$ = blood/water partition coefficient (taken as octanol/water partition coefficient).

A major consideration is the time necessary for the blood to reach equilibrium with the fat. Because this process is slow, the possibility exists for significant elevation of X_b, if V_D as calculated above is used.

To account for this, it was recognized that the NOAEL inhalation exposure were based on seven to eight hours of exposure. Consequently, a safety factor was incorporated in the V_D calculation such that the lipid space was corrected to include only that apparent fat volume which would be filled during 8 hours of exposure.

Thus

$$V_D = V_{TBW} + (V_F \times \lambda_{O/W} \times F_{8h})$$

where

F^{8h} = fraction of final equilibrium level of substance fat after 8 hours.

$$F_{8h} = 1-e^{-kt}$$

$$\ln (1-F) = -kt$$

where

$$k = \frac{\text{plasma flow rate per minute in fat (0.11)}}{V_F \lambda O/W}$$

t = 480 minutes

Dichloropropane

$\lambda_{O/W}$ = 105

F_{8h} = 0.05

V_D = 36 + (10 x 105 x 0.05) = 89

Dichloropropene

$\lambda_{O/W}$ = 43

F_{8h} = 0.11

V_D = 36 + (10 x 43 x 0.11) = 83

Criteria

As stated above:

$$ADI = \frac{\text{Ingestion NOAEL}}{\text{Uncertainty factor}}$$

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The uncertainty factor for both PDC and DCP was taken as 100 based on the fact that the inhalation data utilized appears highly reliable and conversions to ingestion NOAEL had built in underestimation factors.

Finally:

$$CR = \frac{ADI}{2 + (BCF \times 0.0187)}$$

Where

CR = water quality criterion

2 = liters of water consumed per day

BCF = bioconcentration faction in edible portion fish (obtained from USEPA Duluth Laboratory)

0.0187 = estimated consumption (kg) by an individual daily

Dichloropropane

The inhalation NOAEL for PDC is 75 ppm (350 mg/m^3) which is the ACGIH TLV (Am. Conf. Gov. Ind. Hyg., 1977)

$\lambda = 5.5$

$X_a = 350\ \mu g/l$

$X_b = 5.5 \times 0.35 = 1925\ \mu g/l$

$V_D = 89\ l$

$k = 0.25 \times 24\ hr^{-1}$

$$ADI = \frac{0.25 \times 1925 \times 89}{100} = 428\ \mu g/day$$

$BCF = 5.8$

$$CR = \frac{428}{2 + (5.8 \times 0.0187)} = 203\ \mu g/l$$

Dichloropropene

The inhalation NOAEL for DCP is 1 ppm (4.5 mg/m^3) which is that recommended by Torkelson and Oyen (1977).

$$\lambda = 1.4$$

$$X_a = 4.5\ \mu g/l$$

$$X_b = 1.4 \times 4.5 = 6.3\ \mu g/l$$

$$V_D = 83$$

$$k = 0.25 \times 24\ hr^{-1}$$

$$ADI = \frac{0.25 \times 6.3 \times 83}{100} = 1.3\ \mu g/day$$

$$BCF = 2.9$$

$$CR = \frac{1.3\ \mu g}{2 + (2.9 \times 0.0187)} = 0.63\ \mu g/l$$

In summary, based upon the use of an inhalation no-observed-adverse-effect-level in rats (DCP), the ACGIH recommended TLV (PDC), and an uncertainty factor of 100, the criterion level corresponding to the estimated acceptable daily intake of 1.3 µg/day for DCP and 428 µg/day for PDC is .63 µg/l and 203 µg/l, respectively. Drinking water accounts for 95 percent of the assumed exposure for PDC and 98 percent for DCP. The criterion level can alternatively be expressed as 3.9 mg/l for PDC and 24 µg/l for DCP if exposure is assumed to be from the consumption of fish and shellfish products alone.

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